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Patentanmeldung Nr. | Patent application No. | Demande de brevet n°

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Der Präsident des Europäischen Patentamts;
Im Auftrag

For the President of the European Patent Office

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If no title is shown please refer to the description.
Si aucun titre n'est indiqué se referer à la description.)

Cracking furnace

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Title: Cracking furnace

The invention relates to a furnace for thermally cracking a hydrocarbon feed. The invention further relates to a method for thermally cracking a hydrocarbon feed.

Cracking furnaces are the heart of an ethylene plant. In these furnaces feeds, containing one or more hydrocarbon types, are converted into a cracked product gas by thermal cracking in the presence of steam, which acts as a diluent. The cracked product gas is usually rich in ethylene and propylene. Typical examples of hydrocarbon feeds are ethane, propane, butanes, naphta and gasoil.

Cracking furnaces comprise at least one firebox (also known as a radiant section), which comprises a number of burners for heating the interior. A number of cracking tubes through which the feed can pass, are disposed through the firebox. The feed in the tubes is heated to such a temperature that rapid cracking of molecules occurs, which yields desired olefins such as ethylene and propylene. The mixture of hydrocarbon feed and steam typically enters the cracking tubes as a vapour at about 600 °C. In the tubes, the mixture is usually heated to about 850 °C by the heat released by firing fuel in the burners. The hydrocarbons are cracked in the heated tubes and are converted into a gaseous product rich in primary olefins such as ethylene and propylene.

The cracking tubes (in the art also referred to as cracking coils) may be arranged vertically in one or more passes. Conventionally, cracking tubes are arranged in the firebox such that inlet sections and outlet sections are heated essentially equally by the burners. An example of such a furnace is GK6™ (see Figure 1). This furnace comprises two-pass cracking coils arranged in a dual-lane arrangement, wherein inlet sections (extending from inlets 4) and outlet sections (extending outlets 3) are heated essentially equally by the burners 5.

It has been found that this leads to less-optimal cracking conditions. It is thought that this is due to a not so advantageous heat distribution. The cracking process is an endothermic process and requires the input of heat into the feed. For the performance (selectivity) of the cracking process it is desirable to maximise the heat input to the inlet section of the cracking coil (tube). The inventors therefore sought a way to alter the input of heat into the cracking tubes.

It has now surprisingly been found that the input of heat can be altered by designing inlet- and outlet sections of the cracking tubes in a specific way.

Accordingly, the present invention relates to a cracking furnace comprising a firebox provided with cracking tubes – the cracking tubes having at least one inlet section and at least one outlet section - and burners, wherein the outlet sections of the tubes are thermally shielded, in particular more thermally shielded than the inlet sections of the tubes.

Further, the present invention relates to a method for cracking a hydrocarbon feed, comprising passing the feed through at least one cracking tube in a firebox under cracking conditions, wherein the outlet section of said tube is more thermally shielded than the inlet section of said tube. For such method a cracking furnace according to the invention has been found particularly suitable.

The term that an entity (such as a tube section) is "thermally shielded" is defined herein as heat, being hindered to be transferred into the entity. This term is in particular used herein to indicate the extent to which heat generated by the burners during operation of the cracking furnace is hindered to be transferred into the shielded tube. With respect to the outlet sections of the tubes being more thermally shielded than the inlet sections of the tubes, this means in particular that the heat transfer into the cracking tubes at the outlet sections is less than the heat transfer into the cracking tubes at the inlet sections, during operation of the burners.

In principle, shielding can be achieved by placing any heat barrier in between the outlet sections and the burners. For instance thermally insulating coatings or shields can be used. Preferably, shielding in a furnace according to the invention is realising by having inlet sections of the tubes positioned as a thermal shield. This can effectively be realised by having the inlet sections at least partially placed in between the burners and the outlet sections.

The inlet section of a tube is the first part (in the longitudinal direction) of the tube that is inside the firebox, starting from the inlet of the tube into the firebox. It may extend up to the beginning of the outlet section. In particular, it is the part that is less thermally shielded than the outlet section. In a preferred embodiment, the inlet section is the part of the tube that thermally shields the outlet section of the tube, when operating the furnace.

The outlet section of a tube is the last part (in the longitudinal direction) of the tube that is inside the firebox, ending at the outlet of the tube out of the firebox. In particular it is the part that is more thermally shielded than the inlet section. It may extend up to the end of the inlet section. In a preferred embodiment, the outlet section is the part of the tube that is thermally shielded by the inlet section of the tube, when operating the furnace.

It has been found that in accordance with the invention, hydrocarbon feeds can be cracked very well. In particular, the invention is very advantageously employed in the production of ethylene, with propylene, butadiene and/or aromatics as possible co-products.

The hydrocarbon feed to be cracked may be any gaseous, vaporous, liquid hydrocarbon feed or a combination thereof. The invention is *e.g.* suitable to crack gases such as ethane, propane and mixtures of gaseous compounds. The invention is also suitable to crack liquid feeds such as LPG, naphta and gasoil.

It has been found that a furnace according to the invention can be operated with a relatively low temperature difference across the outlet section and thus has a relatively high degree of isothermicity. In a conventional

process in a conventional furnace, the temperature rise of the gas across the outlet section of the tube in a cracking process is typically about 60-90 °C, whereas in a similar process carried out in a furnace according to the invention the temperature rise is usually less, typically about 50-80 °C. Thus the invention allows a reduction of about 10 °C in temperature rise, which is energetically advantageous.

Thus, the average process temperature can be relatively high, allowing for a relatively short residence time, to yield a specific feed conversion, in comparison to a comparable furnace without shielded outlet section. For instance, the residence time for a GK6™ furnace is typically 0.20-0.25 sec, whereas in a comparable process employed in a furnace of the present invention the residence time may be reduced to about 0.17-0.22 sec. Thus the present invention allows for a reduction in residence time of about 15 %, to achieve a particular conversion.

It has also been found that in a furnace according to the invention, respectively with a method according to the invention, a very good reaction selectivity is feasible, showing a relatively low tendency to form undesired by-products.

A typical heat flux profile of a GK6™ furnace and a profile under similar circumstances for a furnace according to the invention are shown in Figure 2A (simulated by SPYRO®, a simulation tool much used for simulating cracking furnaces). In accordance with the invention, it has been calculated that the coil capacity increase in this example (compared to GK6™) is about 10-15 % in throughput, 40 % in run length and/or 1-3 % in olefin selectivity when cracking full range naphtha at the same cracking severity or conversion.

Further, it has been found that a furnace according to the invention can be operated with a low tendency of cokes formation inside the tube, in comparison to some known furnaces, especially at the outlet end of the cracking tubes. Thus, the invention allows for a high availability of the

furnace, as intervals between subsequent maintenance sessions to remove cokes can be increased.

In a furnace according to the invention, the outlet sections of the tubes are advantageously positioned in the firebox in at least one lane, which at least one lane is in between a first lane of burners and a second lane of burners. For practical reasons, the lanes are preferably essentially parallel.

As indicated above, very suitable is a furnace wherein the inlet sections of the tubes act as a thermal shield for the outlet sections, such as in a cracking furnace wherein the inlet sections are positioned in between the outlet sections and the burners. This has been found very efficient, with respect to the heat distribution and achieving a desirable thermal profile throughout the length of the tubes.

Accordingly, in a very advantageous embodiment, the present invention relates to a cracking furnace comprising a firebox, wherein at least one lane of outlet sections of the tubes, at least two lanes of inlet sections of the tubes and at least two lanes of burners are present, in which firebox the at least one lane (O) of outlet sections is located between the at least two lanes (I) of inlet sections and the lanes of inlet sections are located (which inlet sections act as a thermal shield during cracking) in between the at least one lane of outlet sections and the at least two lanes of burners (B). Thus viewing from the top or bottom of the firebox, this configuration can be represented as a B-I-O-I-B configuration.

Examples of highly suitable embodiments are shown in Figures 3, 4, and 5. These examples all show a configuration with inlet and outlet of the tubes at or near the roof and burners being disposed at the opposite of the inlet/outlet ends of the tubes, at the floor and/or the sidewalls. It should be noted that it is also possible to operate a furnace that is rotated relative to the shown configuration, in particular a furnace wherein the inlet/outlet ends of the tubes are at or near the bottom of the furnace. In that case the floor burners are preferably replaced by burners positioned at or near the roof.

The arrangement of outlet sections and inlet sections can advantageously be configured in a herringbone-like arrangement. With such an embodiment a very effective shielding has been found feasible.

Figure 3 shows a cracking furnace with a herringbone-like set up. In this Figure burners 5 are shown at the floor (floor burners 5a) and the side walls (side wall burners 5b), although burners may be placed only at the floor 12 or only at the side walls 9. In general, if side burners are present in a furnace of the invention, these are preferably positioned in the top half of the side walls in case the inlet and outlet are at or near the roof, and vice versa.

In figure 3 (wherein Figure 3A shows a top view intersection and Figure 3B a front view intersection), cracking tubes 2 have their inlets 4 and outlets 3 at or near the roof 11 of the firebox 1. The inlet sections (6, Figure 3B) typically start at the inlet and extend in this embodiment until the part of the tube where the tube bends out of the plane formed by the inlet ends of the tubes, away from the burners towards the centre-line of the furnace. The outlet sections (7, Figure 3B) typically start at the outlet of the tubes. In principle, the outlet section can extend to the position where the inlet section ends. More in particular the outlet section is considered the part of the tube between the outlet and the part of the tube where the tube bends out of the plane formed by the outlet end of the tube.

The section between outlet section and inlet section is then referred to as the middle section 8, which in case the inlet section acts as a shield, is usually shielded at least to some extent. In Figure, 3 the inlet sections are positioned between burners 5 and outlet sections 7, thereby thermally shielding the outlet sections 7.

Figure 4 shows an alternative furnace with an in-line configuration of the outlets. The main distinction with Figure 3 is the arrangement of the tubes, each tube now being essentially perpendicular to the lanes with burners.

Figure 5 shows yet another highly advantageous design, the main difference compared to figures 3 and 4 being the design of the tubes, which now is a two-pass split coil lay out. The coils have two inlets 4 (split flow) and one outlet 3. Figure 5A shows a top view of such furnace. Figure 5B shows a 3-D view of a single coil in such a furnace. Figure 5C and 5D show respectively a side view and a front view of a single coil. In front view (Figure 5D), the appearance of the tube (coil) is more or less m-like or w-like. In case of an m-like shape, the burners are preferably placed at the (lower half of the) sides and/or the roof, instead of at the floor.

Figure 6 shows a furnace with a 4-pass coil, Herein shielding is in particular effected by the part of the tube from a to d and the shielded section in particular comprises the part of the tube from d to g. A furnace with a 4-pass coil, *e.g.* as shown in Figure 6, has been found particularly suitable for cracking a feedstock requiring a relatively long residence time for realising a particular conversion, for instance for the cracking of ethane.

The skilled person will know how to build an apparatus with suitable dimensions, based upon the teaching herein and common general knowledge.

In principle, the design of an apparatus of the present invention can be based upon criteria commonly used when designing a cracking furnace., Examples of such criteria are distances between tubes, between burners and between burners and tubes, tube inlets/outlets, outlet for flue gases, design of the fire-box, burners and other parts.

Burners that fire gaseous fuel are particularly suitable.

The burners may be positioned at any place inside the firebox, in along the floor and/or side walls.

Very good results have been achieved with such a cracking furnace wherein the burners are positioned at the floor of the firebox and the outlet section of the tube extends through the roof of the firebox or at least through a

side wall, close to the roof. Optionally additional burners are present at the side-walls, preferably at least in the top half..

It has further been found advantageous that burners are present at (radially) opposite sides of the tubes. Thus the tubes are fired more equally, than in an embodiment wherein the tubes are fired from only one side. This has been found to lead to more uniform heating in the radial direction of the tubes. An advantage thereof is a lower peak flux to average flux in the radial direction, which is advantageous for maintaining a high degree of isothermicity.

For a symmetrical firing pattern it is further preferred in a furnace according to the invention, that each lane of burners or each of the burners have about the same firing capacity. Analogously in a method of the invention it is preferred that during cracking, each lane of burners or each of the burners generate about the same amount of heat per period of time.

Firing capacity is the heat production per unit of time a burner respectively a lane of burners is capable of. With "the same firing capacity" is meant herein a firing capacity that is essentially equal, *i.e.* having only a variation in capacity that is within normal manufacturing tolerances.

As cracking tubes, those known in the art can be used. A suitable inner diameter is for example chosen in the range of 25-120 mm, depending upon the feedstock quality and the number of passes per coil. The cracking tubes are preferably disposed essentially vertically in the fire-box (*i.e.* preferably the tubes are disposed such that a plane through the tube is essentially perpendicular to the floor of the firebox). The tubes may be provided with features that enhance the internal heat-transfer coefficient. Examples of such features are known in the art and commercially available.

The inlet(s) for the feed into the tube(s) preferably comprise a distribution header and/or a critical flow venturi. Suitable examples thereof and suitable ways to employ them are known in the art.

The outlet sections may suitably be arranged in an in-line configuration (see *e.g.* Figures 3, 4, 5 and 6), wherein the outlets are along a single line along the box (typically along or parallel to the centre line of the box) or a staggered configuration (*e.g.* Figure 7). The staggered configuration may be a fully staggered configuration (*i.e.* wherein three subsequent outlet sections are disposed in a triangular pattern with equal sides (length of a, b and c identical; see *e.g.* Figure 7) or an extended staggered configuration (*i.e.* wherein the outlet sections are disposed in a triangular pattern formed by sides a,b,c (as indicated in figure 7) wherein the side (a) of the extended triangle differs in length from the other sides (b) and (c)

For a very effective shielding of the outlet sections, an in-line configuration has been found very suitable.

In a cracking furnace according to the invention, the pitch/outside diameter ratio is preferably selected in the range of 1.5 to 10 more preferably in the range of 2 to 6. In this context pitch is the distance beween the centreline of two adjacent tubes in the same plane ("c" in Figure 7)

A cracking process according to the invention is usually carried out in the absence of catalysts. Accordingly, in general the cracking tubes in a furnace according to the invention are free of a catalytic material (such as a catalytic bed).

The operating pressure in the cracking tube is in general relatively low, in particular less than 10 bara, preferably less than 5 bara. The pressure at the outlet is preferably in the range of 1.5-3 bara, more preferably in the range of 1.5-2.5 bara. The pressure at the inlet is higher than at the outlet and preferably in the range of 3-4 bara. The pressure difference between inlet and outlet of the cracking tube(s) is preferably 0.5-1.5 bar.

Hydrocarbon feed, typically mixed with dilution steam, is preferably fed to the tube(s), after being heated to a temperature of more than 500 °C, more preferably to a temperature of 580-700 °C even more preferably a temperature in the range of 600-680 °C. In case a (at least partially) liquid

feed is used, this preheating generally results in vaporisation of the liquid phase.

In the cracking tube(s), feed is preferably heated such that the temperature at the outlet is up to 950 °C, more preferably to an outlet temperature in the range of 800-900 °C. In the cracking tubes hydrocarbon is cracked to produce a gas which is enriched in unsaturated compounds, such as ethylene, propylene, other olefinic compounds and/or aromatic compounds. The cracked product leaves the firebox via the outlets and is then led to the heat-exchanger(s), wherein it is cooled, *e.g.* to a temperature of less than 600 °C, typically in the range of 450-550 °C. As a side-product of the cooling steam may be generated under natural circulation with a steam drum.

Examples

A cracking process was simulated for a furnace according to the invention and a GK6 furnace using SYPRO® (See Table 1 for conditions). Figures 2A-2C show the heat flux profiles, the process temperature along the coil and the tube wall along the coil.

Table 1

			Invention		
		GK-6	Equal	Capacity	Selectivity
Total flow	t/h	40	40	45	40
Twall at end-of-run	°C	1100	1100	1100	1100
End-of-run	days	60	80	60	60
CH4 yield	wt.% dry	15.7	15.7	15.7	15.6
C2H4 yield	wt.% dry	27.7	27.7	27.7	28.1
C3H6 yield	wt.% dry	14.1	14.1	14.1	14.3
Relative runlength	%	100%	133%	100%	100%
Relative capacity	%	100%	100%	113%	100%
Relative selectivity	%	100%	100%	100%	101%

Claims

1. Cracking furnace comprising a firebox provided with cracking tubes – the cracking tubes having at least one inlet, at least one inlet section, at least one outlet and at least one outlet section - and burners, wherein the outlet sections of the tubes are thermally shielded, in particular more thermally shielded than the inlet sections of the tubes.

2. Cracking furnace according to claim 1, wherein the outlet sections of the tubes are positioned in the firebox in at least one lane, which at least one lane is in between a at least two lanes of burners.

3. Cracking furnace according to any one of the preceding claims, wherein the firebox comprises at least one lane of outlet sections of the tubes, at least two lanes of inlet sections of the tubes and at least two lanes of burners, wherein the at least one lane of outlet sections is located between at the least two lanes of inlet sections and the lanes of inlet sections are located in between the at least two lanes of burners.

4. Cracking furnace according to any of the preceding claims, wherein at least a number of the burners are positioned at the floor of the firebox and the outlet of the tube extends through the roof of the firebox.

5. Cracking furnace according to any of the claims 1-3, wherein at least a number of the burners are positioned at the roof of the firebox and the outlet of the tube extends through the bottom of the firebox.

6. Cracking furnace according to any one of the preceding claims, wherein at least a number of the burners are placed in a side-wall of the cracking-furnace.

7. Cracking furnace according to claim 6, wherein all the burners are positioned at the side walls.

8. Cracking furnace according to any one of the preceding claims, wherein the outlet sections are arranged in an in-line configuration or a staggered configuration.

9. Cracking furnace according to claim 8, wherein the pitch/outside diameter is selected in the range of 1.5 to 10, preferably 2 to 6.

10. Method for cracking a hydrocarbon feed, comprising passing the feed through at least one cracking tube in a firebox under cracking conditions, wherein the outlet section of said tube is more thermally shielded than the inlet section of said tube.

11. Method according claim 10, wherein the method is carried out in a cracking furnace according to any one of the claims 1-9.

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Title: Cracking furnace

Abstract

The present invention refers to a novel type of cracking furnaces comprising a firebox provided with cracking tubes – the cracking tubes having at least one inlet, at least one inlet section, at least one outlet and at least one outlet section - and burners, wherein the parts of the tubes are shielded. The invention further relates to a process for cracking hydrocarbon feeds, making use of a furnace according to the invention.

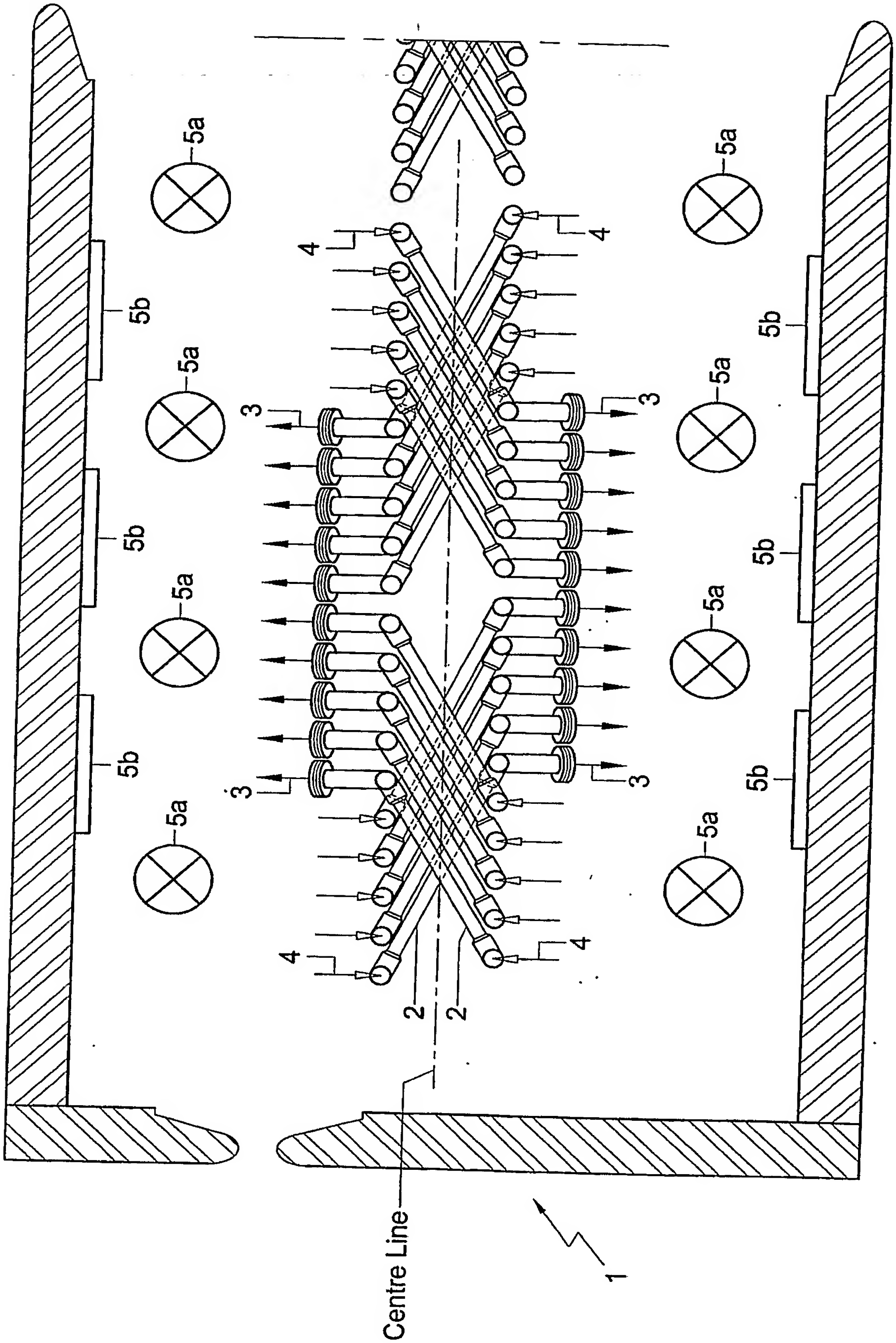


Fig. 1

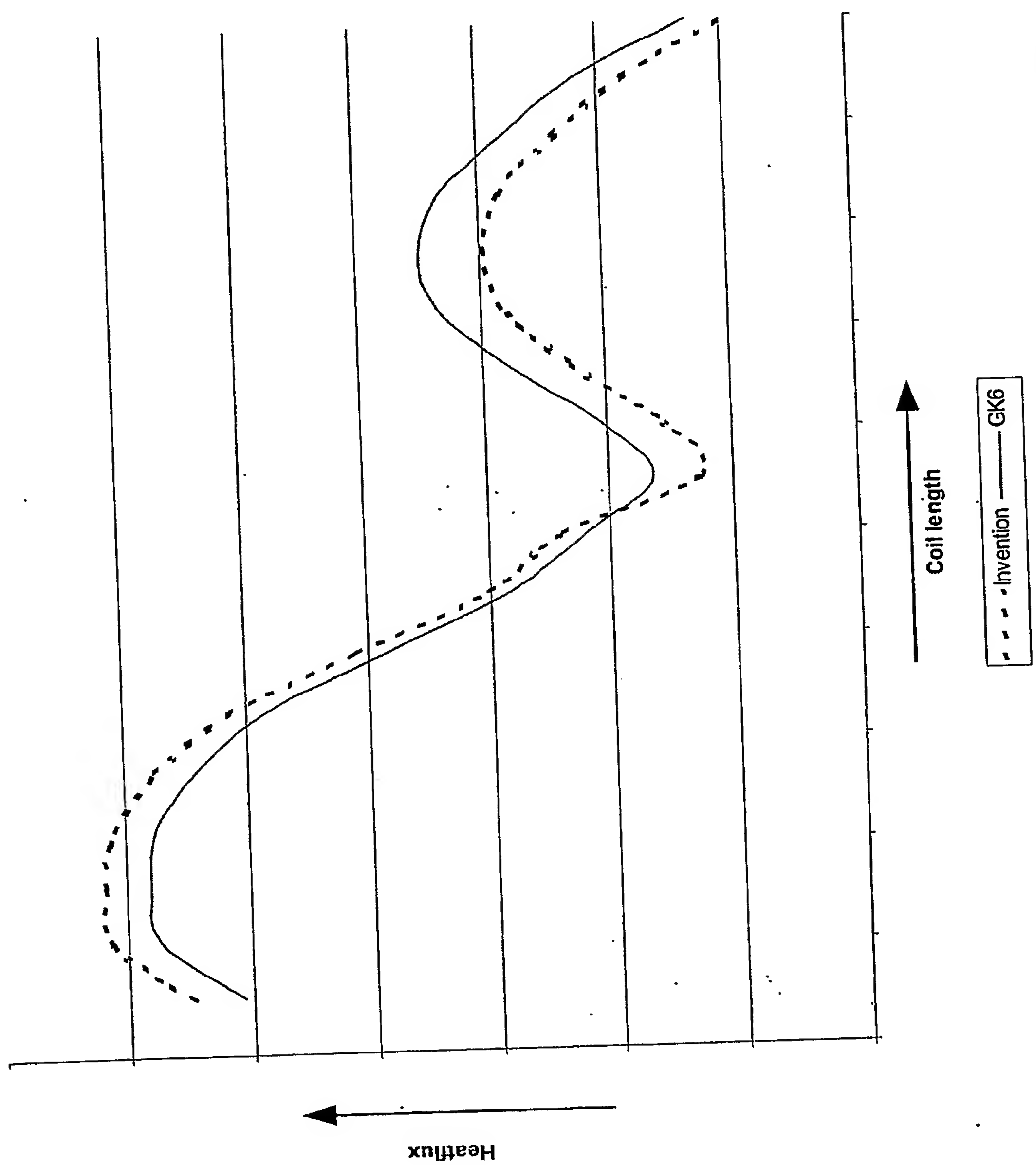


Fig. 2A

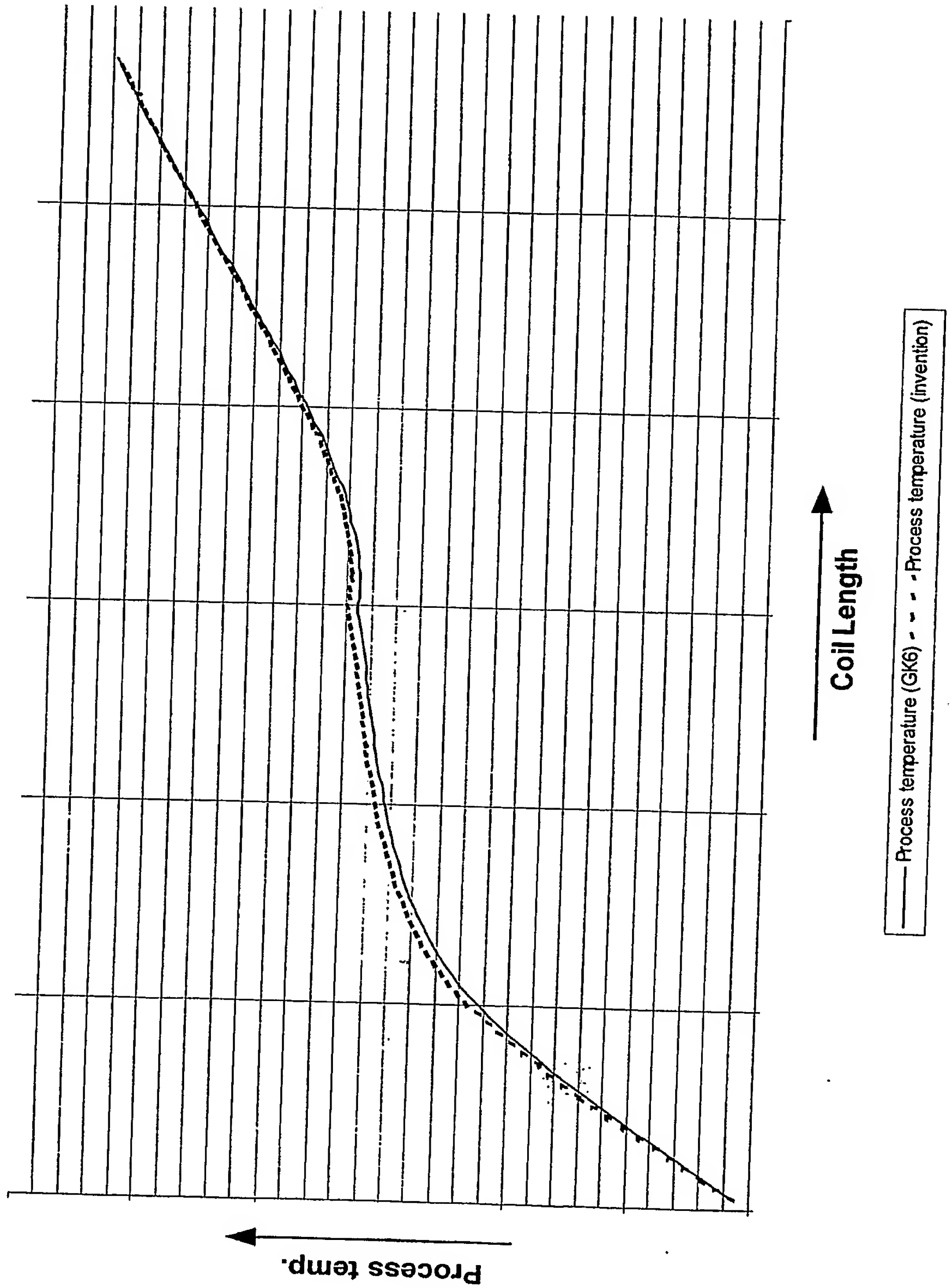

Process temp.
Coil Length
Process temperature (GK6)
Process temperature (invention)

Fig. 2B

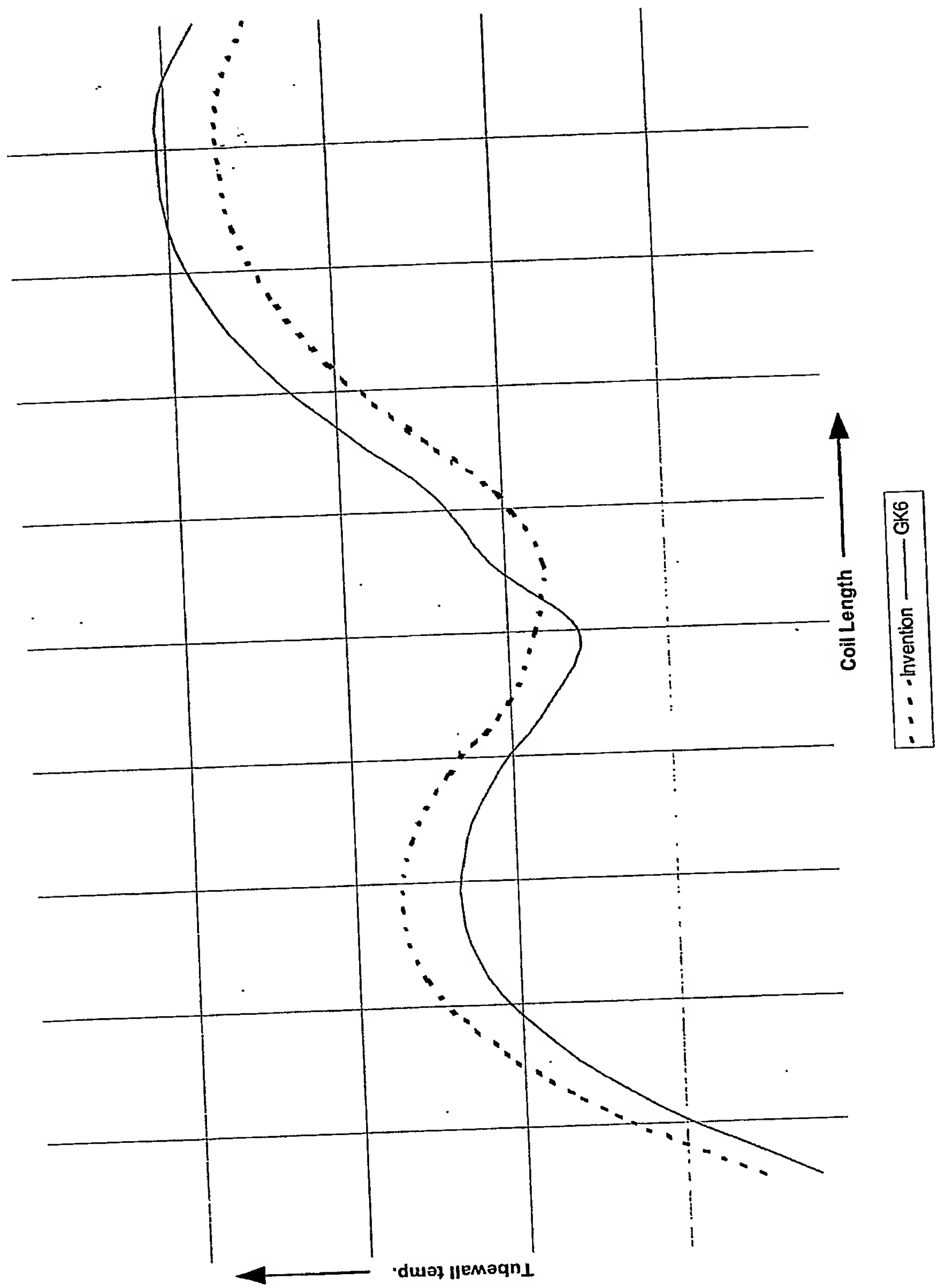


Fig. 2C

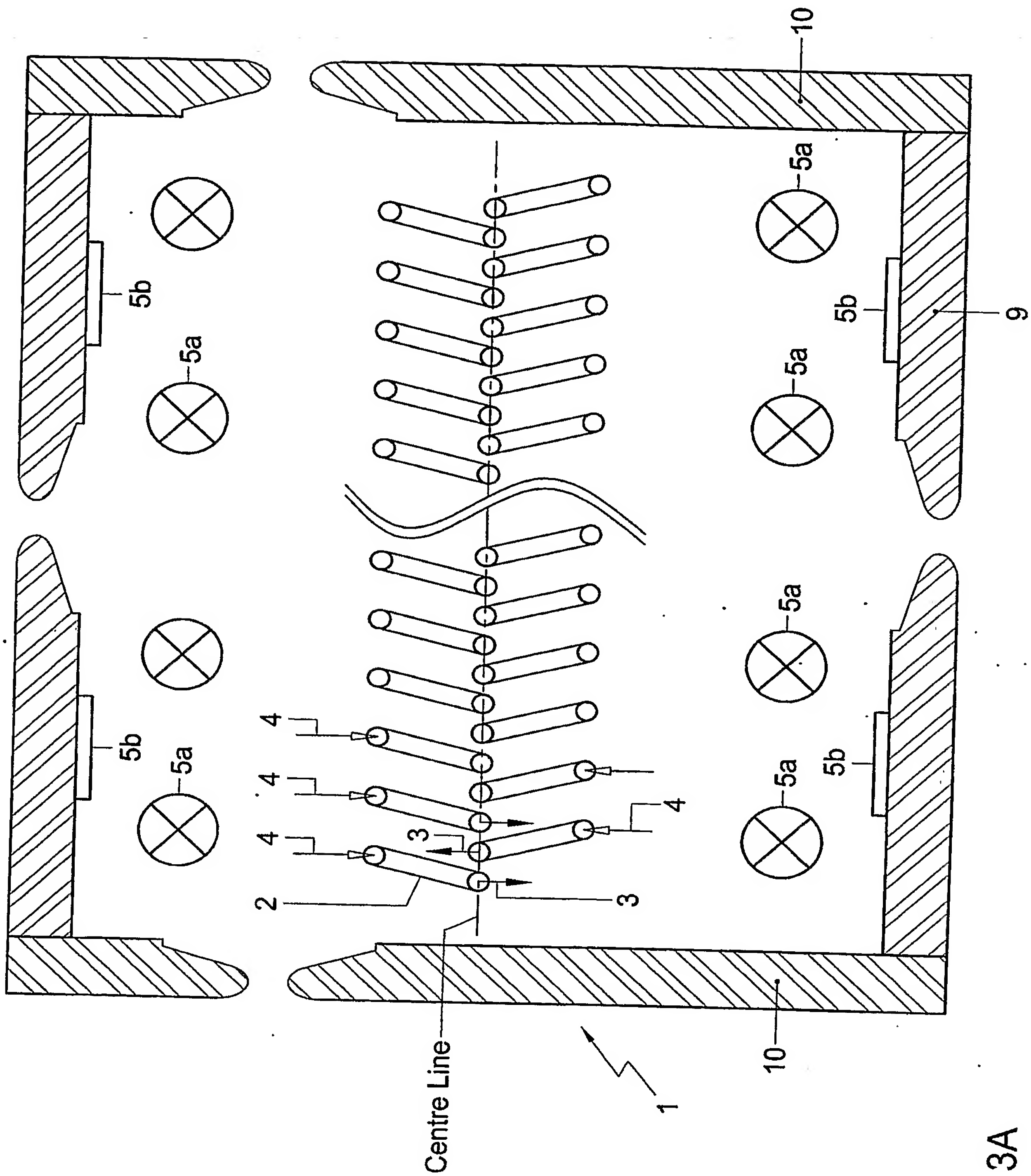


Fig. 3A

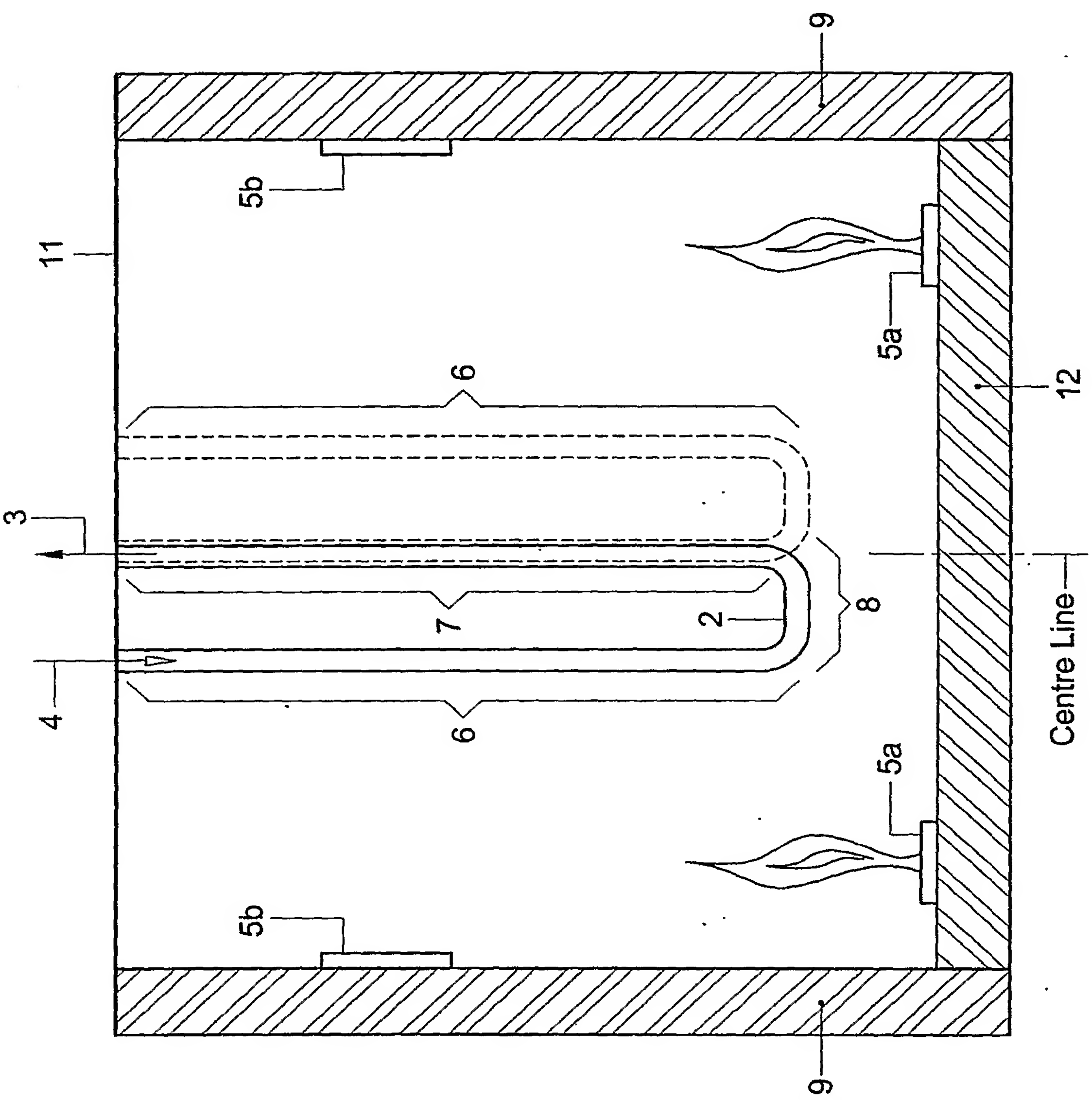


Fig. 3B

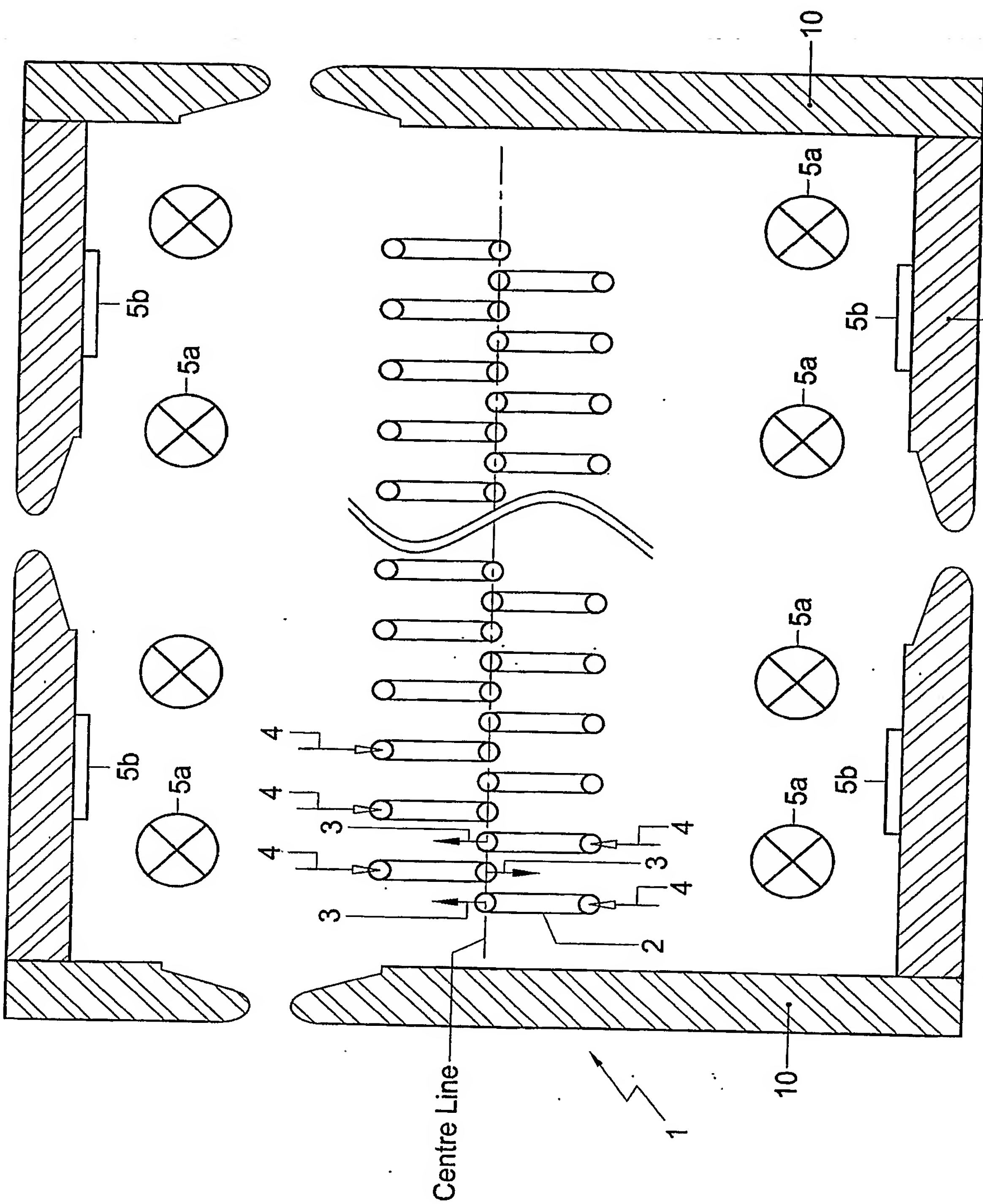


Fig. 4

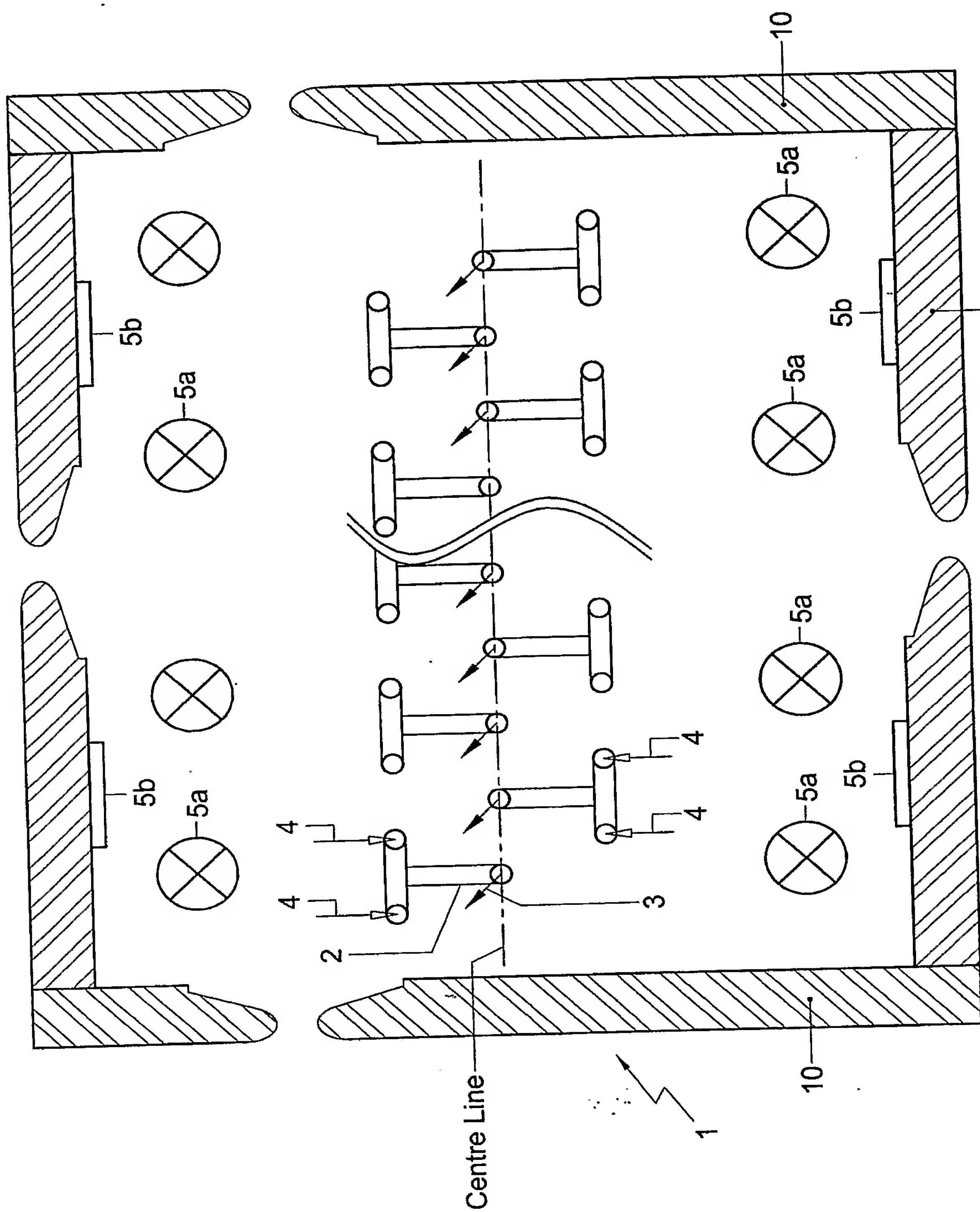
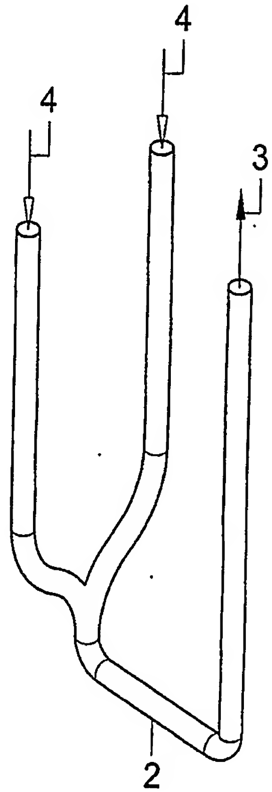
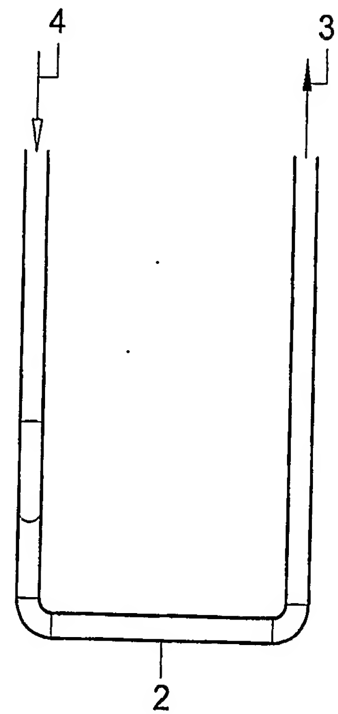


Fig. 5A



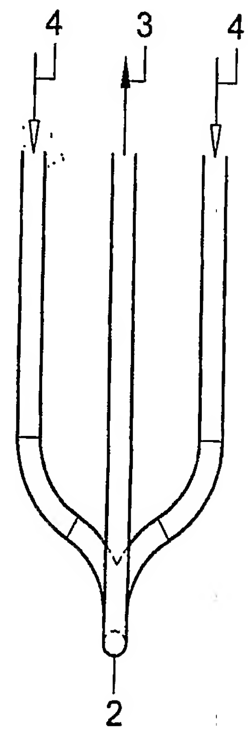
3D View

Fig. 5B



Side View

Fig. 5C



Front View

Fig. 5D

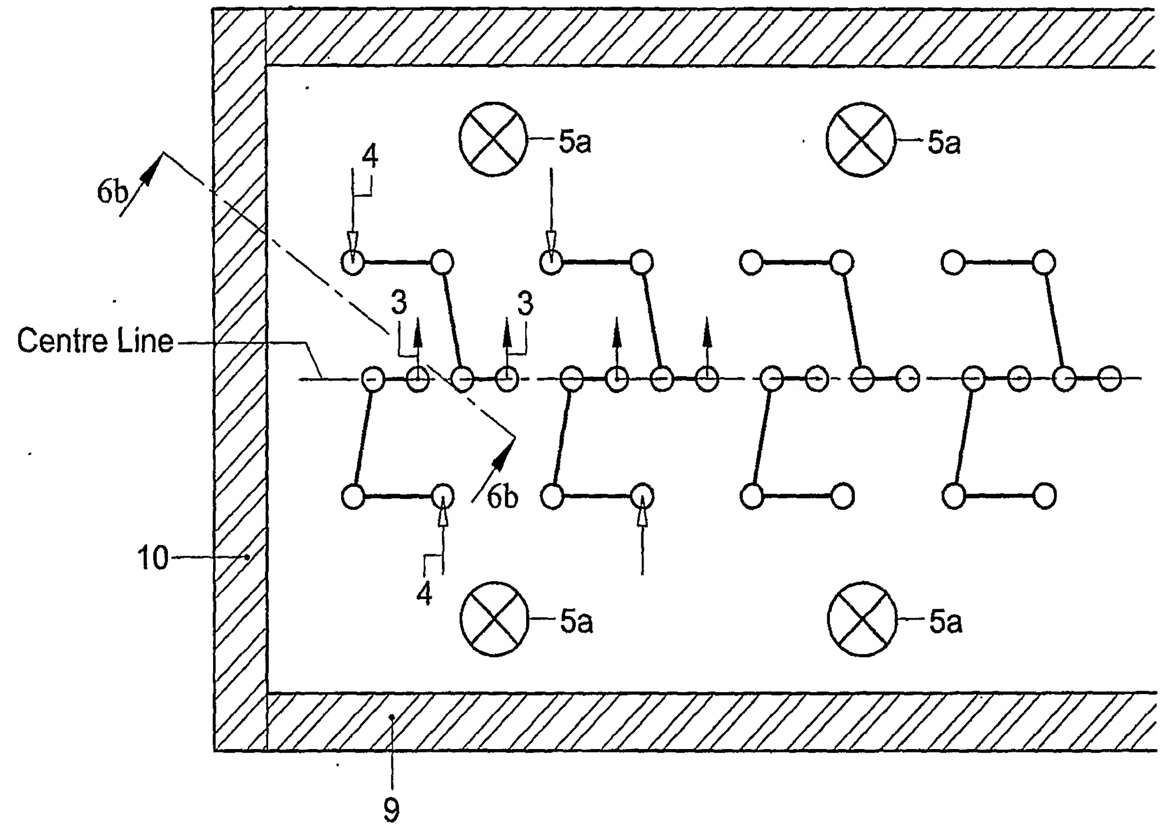


Fig. 6A

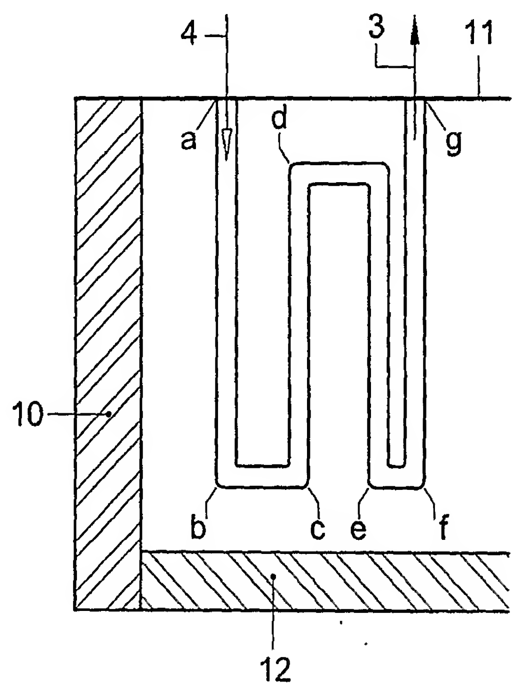


Fig. 6B

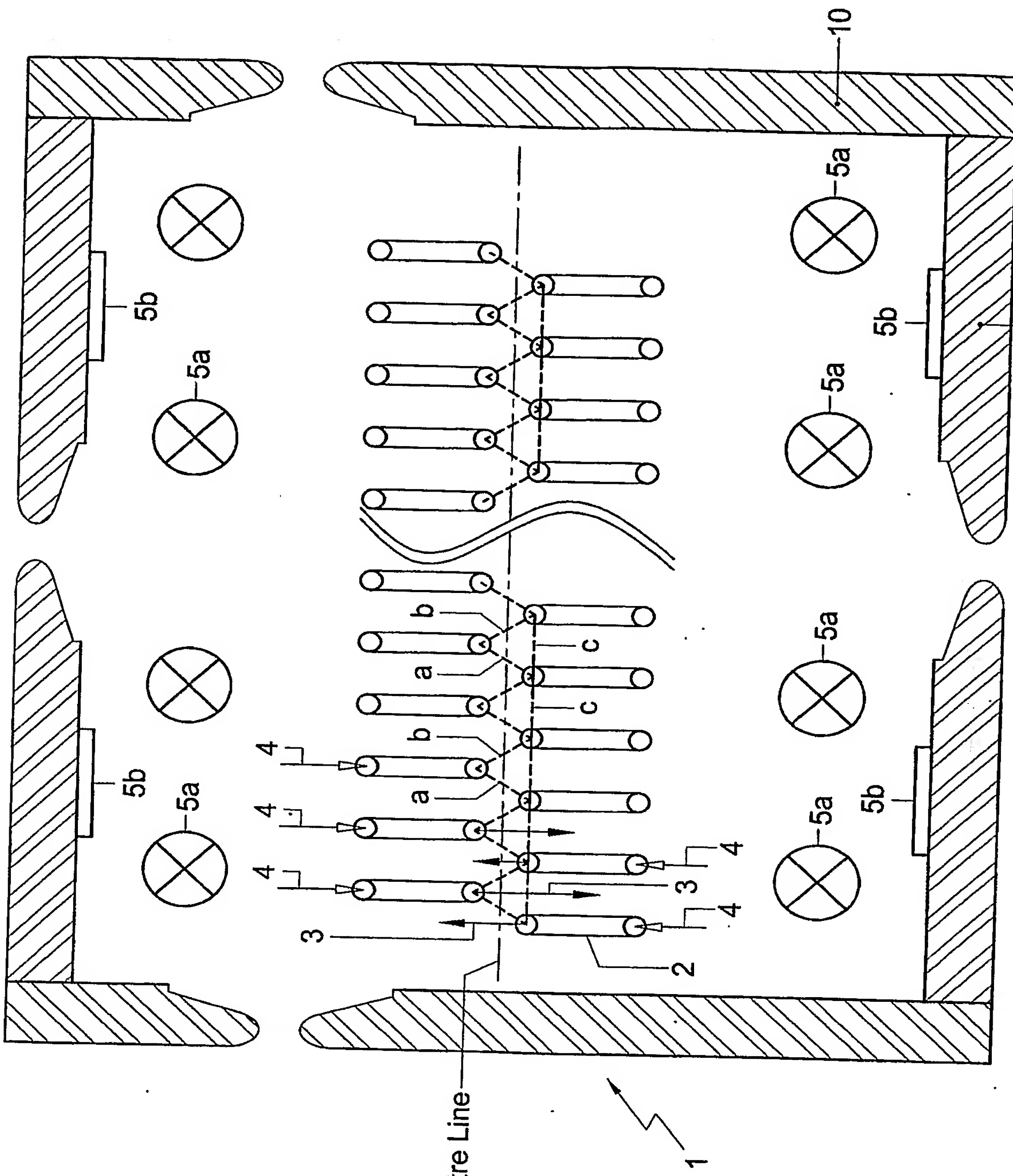


Fig. 7